Evolution of Convectively Injected Water Vapor in the Lower Stratosphere During the SEAC^{4}RS Campaign

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INTRODUCTION

Elevated stratospheric water vapor was observed over the continental United States during the NASA Studies of Emissions and Atmospheric Composition, Clouds and Climate Coupling by Regional Surveys (SEAC^{4}RS) mission in summer 2013. We address the mission question, "Do deep convective cloud systems locally inject water vapor into the overworld stratosphere over the continental United States?" by exploring convective overshooting tops (OT) with observations and models.

Earlier studies based on back-trajectory analysis hypothesized that the source of this excess water was convective storm systems that occurred four days earlier and hundreds of miles away by overshooting the tropopause and irreversibly depositing ice in the stratosphere. Herman et al. (2017) reported that FLEXPART back-trajectories from the aircraft observations intersected identified OT 1-7 days prior from Bedka's OT satellite product (Figure 2).

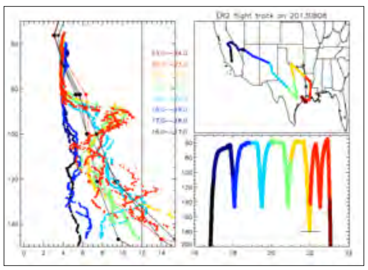
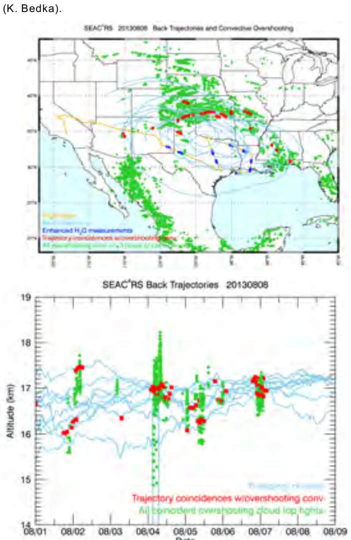


Fig. 1. 8 Aug 2013 observations of LS water vapor by aircraft (JLH) and satellite (Aura MLS). **Left panel:** 8 Aug 2013 H_2O profiles from JLH (dots color-coded by profile), coincident MLS scans (lines with circles), and JLH with the MLS averaging kernel applied (line with asterisks). **Lower right panel:** time series of aircraft pressure color-coded by profile. The MLS overpass and JLH data with averaging kernel applied are all from 22h UTC (yellow). **Upper right panel:** aircraft flightpath (color-coded by profile) and MLS geolocations (asterisks).

FLEXPART Back-Trajectories

Fig. 2 below from Herman et al. (2017).
Upper plot: map of 7-day FLEXPART back-trajectories from enhanced water regions of the aircraft flight, identifying OT coincident with trajectories (red) and +/-3h (green), generated by E. Ray (NOAA).

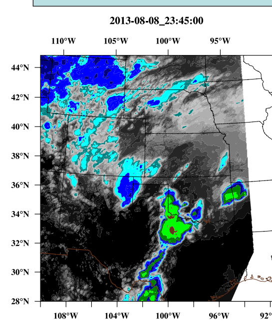
Lower plot: Altitude vs Date plot of FLEXPART back-trajectories with coincident OT (red) and OT at all altitudes (green). OT are from SEAC^{4}RS OT satellite data product (K. Bedka).



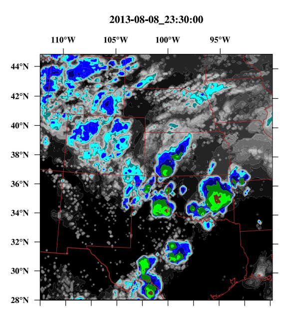
Weather and Research Forecast (WRF) Model

- Model: WRFV3.8.1
- Time period (first 12 hours as spinup):
  "AUG3": 1200 UTC 3 Aug, 2013 – 0000 UTC 9 Aug, 2013
  "AUG7": 1200 UTC 7 Aug, 2013 – 0000 UTC 9 Aug, 2013
- Initial/boundary conditions: NAM_MLS, single moisture profile above 100 hPa from 5 day mean MLS profiles.
- Horizontal resolution: 3 km over single CONUS domain.
- Vertical level: 101 levels with model top at 50 hPa , ~250 m resolution in the UTLS.
- Spectral nudging for wind.
- Physical parameterizations:
  – Morrison 2-moment microphysics
  – RRTMG SW/LW radiation
  – MYJ PBL
  – Noah LSM

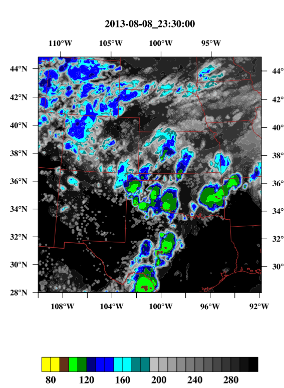
GOES-15 Outgoing Longwave Radiation (OLR).



WRF OLR Initialized 3 Aug 2013

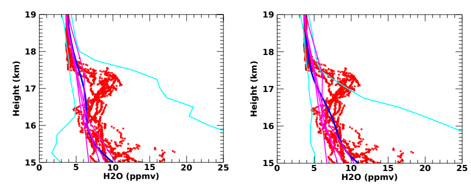


WRF OLR Initialized 7 Aug 2013

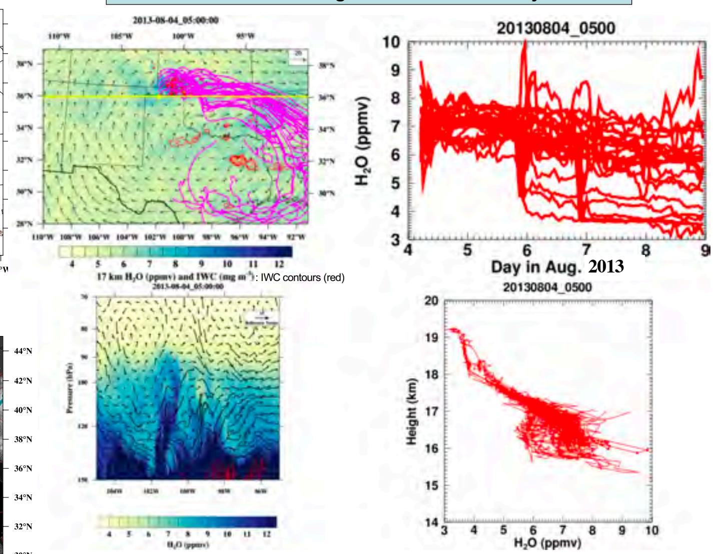


Water Vapor from WRF Simulation

Water Vapor from aircraft (red), MLS (magenta) and WRF (mean: dark blue and range: cyan).
Left: initialized 3 Aug 2013, **Right:** initialized 7 Aug 2013.



WRF Water and Ice along HYPSLIT Forward Trajectories



SUMMARY

- Enhanced H_2O was observed in SEAC^{4}RS aircraft measurements in the lowermost stratosphere between 160 and 80 hPa.
- FLEXPART back-trajectories connect these air parcels to overshooting convective tops up to 7 days earlier.
- WRF simulates convection with OLR pattern similar to GOES 15 observations.
- WRF H_2O is sensitive to boundary condition from reanalysis. Replacing boundary condition with Aura MLS temperature and water improves the simulations of moisture anomalies.
- HYSPLIT forward trajectories with WRF winds provide higher resolution detail of OT indicate *faster* dilution of enhanced H_2O. The WRF model disperses the convectively injected water rapidly on a timescale of 24 hours or less, however, multiple injections of water are seen over August 4-8, 2013.
- Most likely source of enhanced stratospheric H_2O is local convection.

References

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Acknowledgements

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